IGCSE Physics: Space Physics

Syllabus Code: 0625

Learning Objectives

6.1 The Earth and the Solar System

6.1.1 The Earth

- Know that the Earth is a planet that rotates on its axis, which is tilted, once in approximately 24 hours, and use this to explain observations of the apparent daily motion of the Sun and the periodic cycle of day and night
- Know that the Earth orbits the Sun once in approximately 365 days and use this to explain the periodic nature of the seasons

- Know that it takes approximately one month for the Moon to orbit the Earth and use this to explain the periodic nature of the Moon’ s cycle of phases
- Define average orbital speed from the equation $v = 2\pi r / T$ where r is the average radius of the orbit and T is the orbital period; recall and use this equation

6.1.2 The Solar System

- Describe the Solar System as containing: (a) one star, the Sun, (b) the eight named planets and know their order from the Sun, (c) minor planets that orbit the Sun, including dwarf planets such as Pluto and asteroids in the asteroid belt, (d) moons, that orbit the planets, (e) smaller Solar System bodies, including comets and natural satellites
- Know that, in comparison to each other, the four planets nearest the Sun are rocky and small and the four planets furthest from the Sun are gaseous and large, and explain this difference by referring to an accretion model for Solar System formation, to include: (a) the model’ s dependence on gravity, (b) the presence of many elements in interstellar clouds of gas and dust, (c) the rotation of material in the cloud and the formation of an accretion disc
- Know that the strength of the gravitational field (a) at the surface of a planet depends on the mass of the planet, (b) around a planet decreases as the distance from the planet increases
- Calculate the time it takes light to travel a significant distance such as between objects in the Solar System
- Know that the Sun contains most of the mass of the Solar System and this explains why the planets orbit the Sun
- Know that the force that keeps an object in orbit around the Sun is the gravitational attraction of the Sun
- Know that planets, minor planets and comets have elliptical orbits, and recall that the Sun is not at the centre of the elliptical orbit, except when the orbit is approximately circular
- Analyse and interpret planetary data about orbital distance, orbital duration, density, surface temperature and uniform gravitational field strength at the planet’ s surface
- Know that the strength of the Sun’ s gravitational field decreases and that the orbital speeds of the planets decrease as the distance from the Sun increases

- Know that an object in an elliptical orbit travels faster when closer to the Sun and explain this using the conservation of energy

6.2 Stars and the Universe

6.2.1 The Sun as a star

- Know that the Sun is a star of medium size, consisting mostly of hydrogen and helium, and that it radiates most of its energy in the infrared, visible light and ultraviolet regions of the electromagnetic spectrum
- Know that stars are powered by nuclear reactions that release energy and that in stable stars the nuclear reactions involve the fusion of hydrogen into helium

6.2.2 Stars

- State that: (a) galaxies are each made up of many billions of stars, (b) the Sun is a star in the galaxy known as the Milky Way, (c) other stars that make up the Milky Way are much further away from the Earth than the Sun is from the Earth, (d) astronomical distances can be measured in light-years, where one light-year is the distance travelled in (the vacuum of) space by light in one year
- Know that one light-year is equal to 9.5 × 10^15 m
- Describe the life cycle of a star: (a) a star is formed from interstellar clouds of gas and dust that contain hydrogen, (b) a protostar is an interstellar cloud collapsing and increasing in temperature as a result of its internal gravitational attraction, (c) a protostar becomes a stable star when the inward force of gravitational attraction is balanced by an outward force due to the high temperature in the centre of the star, (d) all stars eventually run out of hydrogen as fuel for the nuclear reaction, (e) most stars expand to form red giants and more massive stars expand to form red supergiants, (f) red giants and red supergiants eventually become unstable and eject their outer layers, (g) the remaining core of a red giant becomes a white dwarf, (h) the remaining core of a red supergiant becomes a neutron star or a black hole

Core Content

6.1 The Earth and the Solar System

6.1.1 The Earth

Earth's Rotation and Orbit: * **Rotation:** The Earth rotates on its tilted axis approximately once every 24 hours. This rotation causes the apparent daily motion of the Sun across the sky and the cycle of day and night. * **Orbit:** The Earth orbits the Sun approximately once every 365 days. This elliptical orbit, combined with the Earth's axial tilt, is responsible for the periodic nature of the seasons.

Moon's Orbit: * The Moon orbits the Earth approximately once every month. This orbital motion explains the periodic cycle of the Moon's phases (new moon, crescent, quarter, gibbous, full moon).

Orbital Speed: The average orbital speed (v) of an object can be calculated using the equation:

$$v = 2\pi r / T$$

Where: * r is the average radius of the orbit * T is the orbital period

6.1.2 The Solar System

Components of the Solar System: The Solar System consists of: * **The Sun:** A single star at the center. * **Eight planets:** Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune. Their order from the Sun is important. * **Minor planets:** Including dwarf planets (e.g., Pluto) and asteroids (found in the asteroid belt, mainly between Mars and Jupiter). * **Moons:** Natural satellites orbiting planets. * **Smaller Solar System bodies:** Such as comets.

Inner vs. Outer Planets: * **Inner planets (Mercury, Venus, Earth, Mars):** Rocky and relatively small. * **Outer planets (Jupiter, Saturn, Uranus, Neptune):** Gaseous and large (gas giants).

Accretion Model for Solar System Formation: This model explains the differences between inner and outer planets: 1. **Gravity:** The model relies on gravity to pull matter together. 2. **Interstellar clouds:** The Solar System formed from a rotating cloud of gas

and dust containing many elements. 3. **Accretion disc:** The cloud collapsed under gravity, forming a rotating accretion disc. Denser materials (rock, metals) settled closer to the center, forming the rocky inner planets, while lighter materials (gases) were pushed further out, forming the gas giants.

Gravitational Field Strength: * The strength of a planet's gravitational field at its surface depends on the mass of the planet (more massive planets have stronger fields). * The gravitational field strength around a planet decreases as the distance from the planet increases.

Light Travel Time: Light travels at a constant speed in a vacuum (approximately 3.0 × 10^8 m/s). The time it takes for light to travel a distance can be calculated using `time = distance / speed`.

Planetary Orbits: * The Sun contains most of the mass of the Solar System, and its strong gravitational attraction is the force that keeps planets in orbit around it. * Planets, minor planets, and comets have **elliptical orbits**. The Sun is not at the exact center of these ellipses (except for approximately circular orbits). * The Sun's gravitational field strength decreases with distance, and consequently, the orbital speeds of planets decrease as their distance from the Sun increases. * Objects in elliptical orbits travel faster when they are closer to the Sun and slower when they are further away. This is explained by the **conservation of energy** (gravitational potential energy is converted to kinetic energy and vice versa).

6.2 Stars and the Universe

6.2.1 The Sun as a star

Characteristics of the Sun: * The Sun is a medium-sized star. * It consists mostly of hydrogen and helium. * It radiates most of its energy in the infrared, visible light, and ultraviolet regions of the electromagnetic spectrum.

Stellar Power Source: * Stars, including the Sun, are powered by **nuclear reactions** that release immense amounts of energy. * In stable stars, these nuclear reactions primarily involve the **fusion of hydrogen into helium** in their core.

6.2.2 Stars

Galaxies and the Milky Way: * **Galaxies** are vast systems, each made up of many billions of stars, gas, dust, and dark matter. * The Sun is a star located in the **Milky Way galaxy**. * Other stars in the Milky Way are much further away from Earth than the Sun.

Astronomical Distances: * Astronomical distances are often measured in **light-years**. * One light-year is the distance light travels in a vacuum in one year. * `1 light-year = 9.5 × 10^15 m`.

Life Cycle of a Star: 1. **Formation:** A star begins its life from an **interstellar cloud of gas and dust** (primarily hydrogen). 2. **Protostar:** The cloud collapses under its own gravity, increasing in temperature and density, forming a **protostar**. 3. **Stable Star:** A protostar becomes a stable star when the inward force of gravitational attraction is balanced by an outward force due to the high temperature and pressure from nuclear fusion in its core. 4. **Hydrogen Depletion:** All stars eventually run out of hydrogen fuel for nuclear reactions. 5. **Red Giant/Supergiant:** * Most stars (like our Sun) expand to form **red giants**. * More massive stars expand to form **red supergiants**. 6. **Ejection of Outer Layers:** Red giants and red supergiants eventually become unstable and eject their outer layers, forming planetary nebulae. 7. **Remnant:** * The remaining core of a red giant becomes a **white dwarf** (which slowly cools down). * The remaining core of a red supergiant collapses further to form either a **neutron star** or, if sufficiently massive, a **black hole**.

Key Terms

- **Rotation:** Spinning of a celestial body on its axis.
- **Orbit:** The curved path of a celestial object around a star, planet, or moon.
- **Orbital Speed:** The speed at which an object travels in its orbit.
- **Solar System:** The Sun and all the celestial bodies gravitationally bound to it.
- **Planet:** A celestial body orbiting a star, massive enough to be rounded by its own gravity, and has cleared its orbit of other debris.
- **Dwarf Planet:** A celestial body orbiting the Sun, massive enough to be rounded by its own gravity, but has not cleared its orbit of other debris.
- **Asteroid:** A small rocky body orbiting the Sun.

- **Comet:** A celestial body composed of ice and dust, orbiting the Sun, and developing a tail when near the Sun.
- **Accretion Model:** Explains the formation of the Solar System from a rotating disc of gas and dust.
- **Gravitational Field Strength:** The force per unit mass experienced by an object in a gravitational field.
- **Light-year:** The distance light travels in one year.
- **Galaxy:** A vast system of stars, gas, dust, and dark matter.
- **Milky Way:** The galaxy containing our Solar System.
- **Protostar:** A contracting mass of gas that represents an early stage in the formation of a star.
- **Red Giant:** A large, cool star in a late stage of stellar evolution.
- **Red Supergiant:** A very large and luminous red giant star.
- **White Dwarf:** A small, dense, hot star, typically the size of a planet, formed when a low-mass star has exhausted all its central nuclear fuel and lost its outer layers.
- **Neutron Star:** A very dense, compact star composed primarily of neutrons, formed from the collapsed core of a massive star.
- **Black Hole:** A region of spacetime where gravity is so strong that nothing, not even light, can escape.

Summary

This study guide has explored the fascinating realm of Space Physics, covering the dynamics of our Earth and its Moon, the structure and formation of our Solar System, and the life cycles of stars, including our Sun. We have examined orbital mechanics, gravitational forces, and the vast scales of astronomical distances. This knowledge provides a comprehensive understanding of our place in the universe and the fundamental physical processes governing celestial objects.